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## AN APPARATUS FOR THE STUDY OF KINÆSTHETIC SPACE PERCEPTION.

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The accompanying drawing reproduces the apparatus as set up for forearm movements.

The subject sits or stands with the arm over the lever (*L.*). The hand-holder (*H. H.*) is put at such a distance from the shaft (*S.*) that the centre of the elbow joint is opposite the end of the shaft. The forearm does not rest on the lever, but is entirely supported at one end by the hand-holder, and at the other by the upper arm. Thus, only the hand of the subject is in contact with the instrument, unless, instead of making use of the hand-holder, the forearm be tied to the lever by a soft bandage. (See below, No. 5.) When the point of the lever indicates zero on the scale, the upper arm hangs vertically from the shoulder and the forearm is horizontal.

The two essential dispositions of the apparatus are the following:

1. The arm movements produce the rotation of a shaft placed at right angles to the plane described by the moving arm and directed towards the centre of rotation of the arm, *i. e.*, the elbow joint.

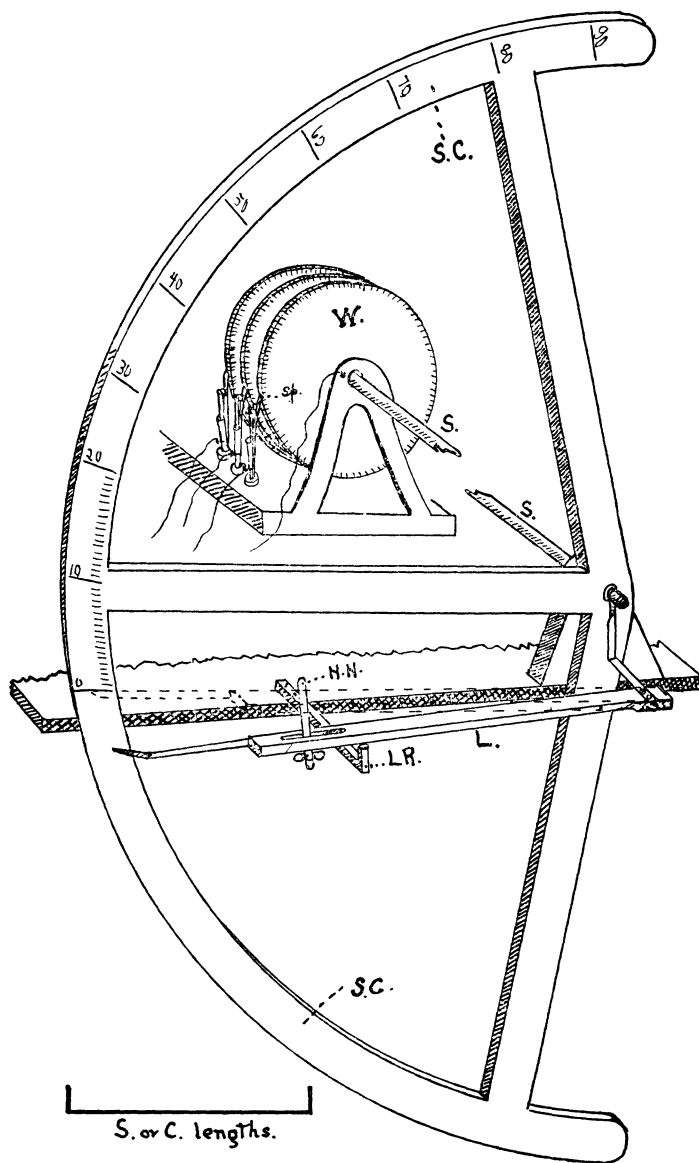
2. On this shaft a wheel (*W.*) of non-conducting material (fibre) is fixed, bearing across its edge metallic blades at equal distance from each other. These blades are connected with the axis of the wheel, and the axis with an ordinary recording magnet with which is also connected a spring (*sp*) pressing against the edge of the wheel. Thus an electric circuit is completed whenever one of the blades passes under the spring and recorded on a kymograph drum.

As an ordinary recording magnet cannot be made to move at a greater speed than 100 movements a second, several wheels may be used. If three wheels, each connected with a separate recording magnet, be used and the distance between the blades on the rims of each wheel be 2 degrees, movements of any velocity, up to 450° a second (that is,  $\frac{2}{3} \times 300$ ), can be recorded.

The wheels are to be adjusted on the axis so that they produce contacts successively and not simultaneously.

The distance between each two successive downward move-

ments made by each one of the recording magnets corresponds to an arm movement of  $2^{\circ}$ . But by combining the lines traced



by the three markers, the distance of two successive movements corresponds to  $\frac{2}{3}$  of a degree. Thus the length of the arm movements, wherever made on the semi-circle, can be computed on the kymograph records. If a time line be added, the total duration of the movement as well as its velocity at any point can be read.

This method of determining the length and the duration of a movement is evidently subject to an error, an underestimation: the movements begin to be recorded only when the first contact is made, and cease to be registered when the last contact takes place, although the movement usually begins a little before and continues a little after. But the average amount of this underestimation, depending as it does upon the distance of the blades from each other, is easily calculated. Moreover, this error affects equally, on the average, the standard and the comparison movements. It can, therefore, be looked upon as immaterial, at least when the movements have a certain length and when the number of tests is sufficiently large.

It should not be overlooked, however, that one is not dependent upon the drum records for a knowledge of the length of the movements. Except when the movement is a free-ending one, the lengths of both the standard and the comparison are determined by the operator himself. And as to the free-ending comparisons, their lengths can be read directly on the semi-circle (*S. C.*).

The duration error mentioned above can easily enough be done away with by discarding the wheels, connecting the end of the lever (*L.*) with the recording apparatus, and using metallic standard and comparison lengths (*S.* and *C.* lengths) also connected with the recording magnets. These lengths may be made of sheet metal bent at both ends and placed wherever wanted on the semi-circle. In the initial position the point of the lever is in contact with one of the bent ends and in the final position, with the other. Thus an electric contact is broken at the beginning of the Standard and of the Comparison and one is made as they are completed. This method, used by us in several series, has its advantages and its drawbacks. It cannot, of course, be used when the comparison is to be a free-ending movement. And the click produced by the end of the lever striking the ends of the metallic lengths is an undesirable complication.

This apparatus meets, to some extent at least, a need long felt in the study of kinæsthetic space perception by means of arm and leg movements. Its chief uses and advantages are as follows:

1. The movements are arc movements, *i. e.*, movements involving but one joint and the muscles operating it.

2. It is usable for movements of the forearm only, or of the whole arm, of any length and at any point of the arc the arm can describe. The accompanying drawing represents the apparatus set up for the study of vertical movements; but it can be set up for the investigation of movements in the horizontal plane.

3. It can be used for active and for passive movements, and also for the study of the influence of resistance. For this last purpose, a weight is attached to a wire running in a groove made in the rim of one of the wheels.

4. In the case of movements of the fore-arm in the vertical plane, the upper arm hangs freely from the shoulder, and thus disturbing strain elements, present in most of the other methods, are eliminated.

5. It does away with the sensation-complications produced by holding a pencil and drawing a line, or by marking the beginning and the end of the lengths by a pressure. For it was found easy for the observer to maintain practically the same pressure on the hand-holder (*H. H.*) from the warning signal to the return to the rest position. It may be preferable, however, to tie the arm to the lever, and thus do away with the possibility of changes in the hand pressure synchronous with the movements compared.

6. Used as we have used it, it is soundless. The only parts of the apparatus which make any noise are the wheels (*W.*) in rubbing against the springs (*sp*) and the recording instruments. In our experiments these were placed in a room adjacent to the one occupied by the observer.

7. The elimination of the sensations arising from contact of the air with the skin of the arm and hand, is secured by the use of a loose glove which reaches nearly to the elbow where it is covered by a loose sleeve. This, together with the elimination of sound and of the other disturbing sensations already referred to, leaves as factors to be considered practically only the joint, the tendon, and the muscle sensations. The direction of the attention to one or the other of these is thus made considerably easier.

8. It provides for the recording of the duration of movements of any length, performed at any point of the arc described by the arm, in both directions. It may thus be used for an exact study of the duration and of the velocity factors in the estimation of spatial arm movements. Free movements are recorded and timed as well as those that are objectively limited.

9. The apparatus can easily be adapted to the study of leg movements.